7110.3REV1T/TempGdlns-ClgHtdProds012489

REVISION 01 01/24/89

OPI: TS/PPID

TIME/TEMPERATURE GUIDELINES FOR COOLING HEATED PRODUCTS (CON'T)

III. HOLDING TEMPERATURES

A. COLD STORAGE TEMPERATURES

35 degrees F. rather than 40 degrees F. should be used to store uncured processed product for any period of time longer than one week.

B. INTERMEDIATE HOLDING TEMPERATURES

These time and temperature guidelines apply to the holding of heated products before cooling them to 40 degrees F. Products heated above 155 degrees F. then cooled from 130 degrees F. to 60 degrees F. within 2 hours should remain unadulterated for up to 4 hours if they are:

1. kept below 60 degrees F. during the 4 hours,
2. protected from post-cooking contamination, and
3. cooled to 40 degrees F. within 2 hours, at the end of the 4 hour holding period.

C. HOT HOLDING TEMPERATURES

Uncured cooked products may be safely held for up to 4 hours if kept above 130 degrees F., or for an extended period if kept above 140 degrees F. If product drops below 130 degrees F. for over 30 minutes, the processor should either continuously cool it to meet the times and temperatures in II. B. above, immediately reheat it to 160 degrees F., or condemn it. CAUTION: Processors should not attempt to hold product below 140 degrees F. unless they have established good temperature control over all portions of the product. Thus, processors should keep product above 140 degrees F. when it is in transit, in containers without temperature monitoring, or in similar cases where good control is not established and maintained.

IV. MONITORING

To safely use these more flexible cooling rates, processors must accurately monitor the product's internal temperature. FSIS suggests that temperature recorders are generally the best and most economical means. Additional recommendations for temperature monitoring follow:

A. THE MONITORING DEVICE

1. Accuracy: The temperature recording devices should be both readable and accurate to 2 degrees F. and 5 minutes within the critical range. The processor should check the manufacturer's accuracy specifications before purchasing a unit, e.g., a unit accurate within 1 percent of range and a range of O degrees F. to 250 degrees F. is not accurate enough. However, a processor can verify that some of these instruments are in fact sufficiently accurate by careful calibration at two temperatures within the critical temperature range. (See subparagraph 2. below.)

2. Calibration: Processors should check each new instrument for accuracy regardless of the manufacturer's claims; rough handling during shipping can undo the factory calibration. Although electronic instruments are resistant to rough handling, they too should be checked. The processors should calibrate both time and temperature accuracy against known standards.

a. Temperature calibration standards: The most practical and reliable temperature standard for this purpose is a mercury-in-glass thermometer which conforms to the standards of the American Society for Testing Materials (ASTM). In most cases ASTM requires that thermometers bearing their initials be accurate within one scale division. A review of ASTM Standard E-l, Standard Specification for ASTM Thermometers, will present the processor with a choice of several ASTM thermometers having a maximum scale error of less than 20 degrees F. The ASTM 64 degrees F. thermometer would be an excellent choice for calibrating in the range of 80 to 130 degrees F. The ice point at 32 degrees F. is a reference point for temperature calibration and is used to detect changes in the reading of the standard mercury-in-glass thermometer due to changes in the volume of the bulb with time.

b. Calibration procedure: Immerse the probe and standard into a substance with a uniform temperature; FSIS recommends a stirring water bath within 20 degrees F. of the critical temperature the measuring device will have to monitor. For these cooling guidelines, a water bath at 105 degrees F. would suffice, however, calibrating the device at two temperatures within the 130 degrees F. and 80 degrees F. range is better.

c. Verifying the accuracy of uncertified thermometers: A processor with a thermometer that the manufacturer does not certify to be accurate within 2 degrees F. and 5 minutes may be able to verify that it is adequate by checking it at several standard temperatures within the critical temperature range. For these cooling guidelines, FSIS recommends verifying that the measured temperatures at 130 degrees F., 80 degrees F., and 40 degrees F. are accurate.

B. TEMPERATURE MEASUREMENT

1. Number of probes: The number of probes or temperature sensing devices needed varies with the circumstances. Processors should depend on their QC resources to determine the appropriate number and placement.

2. Frequency of monitoring: Initially the plant should monitor every lot. However, if the plant builds a history of excellent compliance, reduced monitoring should not add unacceptable risk. Processors should consult with their QC specialists for applications to their specific plant.

C. RECORDS

Processors should keep records of all time and temperature checks for at least 1 year, even though the product may have a shelflife of only 60 days. A record of good manufacturing practice is valuable insurance, and an invaluable reference for improving future performance.

V. VARIANCES IN COOLING RATES

These guidelines contain a safety margin; therefore, a small lapse in and of itself will probably not cause a problem in every instance. However, a large variance or continual small ones constitute unacceptable risk. In addition, the processor should consider an occasional small variance an opportunity to find and correct a control problem.

A. UNACCEPTABLE VARIANCES

If the number of minutes of product cooling time exceeds the minutes of guideline time by more than 25 percent, the processor should take the following actions:

1. Notify the inspector, the QC unit, and other concerned units such as refrigeration maintenance and production.

2. Hold the involved product and examine it for potential adulteration by bacteria, particularly clostridial pathogens. If it is adulterated, inform the inspector.

3. Postpone further product manufacturing utilizing that chill facility until the processor has:

    a. determined the cause of the variance;

    b. completed adjustments to assure that the variance will not recur; and

c. informed the inspector and the production units of the determinations and adjustments and made any needed amendments in the written processing procedures.

If the number of minutes of product cooling time exceeds the minutes of guideline time by any percentage twice or more in any consecutive 2O-day-period of production, the processor should take the following actions:

1. Notify the inspector, the QC unit, and other concerned units such as refrigeration maintenance and production.

2. Postpone further product manufacturing utilizing that chill facility until the processor has:

a. determined the cause of the variance;

b. completed adjustments to assure that the variance will not recur; and

c. informed the inspector and the production units or the determination and adjustments and made any needed amendments in the written procedures.

B. OTHER VARIANCES

If the actual cooling time exceeds a guideline time by less than 25 percent once during any 20-consecutive-day period of production, the processor should:

1. Notify the inspector, the QC unit, and other concerned units such as refrigeration maintenance and production;

2. Investigate and determine the cause of the variance;
3. Complete any needed adjustments to assure that the variance will not recur;

4. Inform the inspector and production unit of the determinations and adjustments; and

5. Make any needed amendments in the written processing procedures.

VI. ALTERNATE COOLING PROCEDURES

Processed Products Inspection Division based these guidelines on the best available information and is providing them for general application. We will modify the general guidelines if we have additional information to warrant it. In addition, Processed Products Inspection Division will consider alternate cooling procedures which processors may propose for their specific products and processes.

A. BASIS FOR ACCEPTABLE ALTERNATE PROCEDURES. Acceptable alternate procedures should be based on reliable information that assures the safety of the procedure. Either:

1. Original scientific research, developed from a previously accepted research protocol, which establishes the safety of the alternate procedure with respect to the probable pathogens concerned and identifies the critical factors; or

2. A letter or report by a processing authority that the proposed procedure is appropriate for the product proposed, considering the processing method, the packaging method, the handling involved, and the pathogens considered. This should be supported by an appropriate review of the relevant scientific literature and any original data.

B. CONTENT OF ACCEPTABLE ALTERNATE PROCEDURES Acceptable alternate cooling procedures should include:

1. A description of the cooling procedure, including:

a. The critical control points

b. A map of the cooling facility and the product arrangement within it

c. A description of the cooling facility's refrigeration capacity and coolant flow

2. An explanation of how the plant will control the procedure, including:

a. A product temperature monitoring program that is at least equal to that in Division IV of this guideline

b. The product processing procedure including controls over product formulation and composition

c. How the critical control points will be controlled

d. Written employee instructions as to how cooling is to be done, how monitoring is to be done, and how variances should be handled.

VII. IMPROVING PRESENT COOLING

We have added this Division to the Guidelines to help processors consistently satisfy our recommended cooling rates, thus producing higher quality products and also saving energy and the money that energy represents. We have based the following information on our experience with solving cooling problems and the scientific expertise of the USDA's

Agricultural Research Service.

A. COMMONLY KNOWN FACTS ABOUT COOLING

Some of the means for improving product cooling are commonly known because we all are continually exposed to some form of cooling; winter winds, metal stadium seats, or cold swimming pools are some of the examples. We have also learned to minimize the chilling effects of these factors by standing out of the wind, sitting on cardboard, or wearing a wetsuit. But we don't always apply what we know in one context to another. Thus, we have devised this Division to stimulate processors to apply their present knowledge to improving food cooling. We have also included two simplified formulas to aid in quantifying the effect of different cooling practices and added a cooling practice checklist.

B. HEAT FLOW

Processors planning cooling improvements should consider how heat moves from the product's center to it's surface and ultimately to the exterior of the plant. A simplified diagram would be:

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(PRODUCT) (PRODUCT)            (REFRIGERATOR)(REFRIGERATOR) (CENTER)-
>(SURFACE)->(COOLANT)- > (EVAPORATOR)->(CONDENSER)->(AIR)
              (COIL)       (COIL)
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The rate at which heat flows between these preceding steps is governed by the laws of heat transfer. By understanding the gist of these laws, and applying them to cooling procedures, the processor can improve cooling efficiency.

C. PHYSICAL LAWS OF HEAT TRANSFER

1. Fourier's and Newton's Laws describe the factors affecting heat transfer from the food product until it is ultimately transferred to the outside environment. Understanding these laws will help you understand how to improve your cooling rate.

A simple expression of Fourier's law of heat transfer is:

$$q = \frac{k \times A \times dT}{L}$$

Newton's Law of cooling by convection is:

$$q = h \times A \times dT$$

q is the rate of heat transfer (BTU/hr)

k, for Fourier's Law, is the thermal conductivity constant (ice is

1.28; cold water is .32; meat is .29; stainless steel is 9.4)

h, for Newton's Law of Convection, is the heat transfer coefficient (still air = 0.5 to 5; fanned air = 2 to 20; stirred water = 100 to l000)

A is area for heat transfer (sq ft)

dT, in Fourier's Law, is the difference in temperature between the surface and center (degrees F.) or in Newtons's Law, the difference in temperature between the food and coolant

L is the distance the heat must move (ft)

2. To better understand what these laws mean to you, imagine what would happen if you tried the following experiments:

a. The effect of "A" & "L": Take two 5 pound warm meatballs and mash one to 1 inch thickness, net both, then hang them in the same cooler. Experience tells you that the mashed meatball will cool faster; so does Fourier. For the mashed meatball, "A" is higher and "L" is lower, thus q, the rate of heat transfer, will be higher.

The factors are multiplied in Newton's and Fourier's laws. Thus, halving any factor (except "L") halves "q", the rate of heat transfer; halving "L", doubles "q" .

b. The effect of "A", "L" & "k": Next, take two identical 5 pound meatballs mashed to 1 inch thickness. Put one on a plastic foam tray, the other on a stainless steel tray, and place both in the same area of the cooler. Because the plastic tray conducts very little heat, it effectively reduces "A" by almost half (the 1 inch edge would remain the same). Conversely, the stainless steel tray conducts heat more rapidly than the air and effectively acts as a large fin, thus "dT" will be higher at the bottom surface of the meat than at the top. Experience reinforces this logic; leaning against a steel wall will chill you faster than leaning against a wooden or plastic foam wall.

c. The effect of "h" & "dT": The coefficient of heat transfer (h) for stirred air is approximately 50 times that for still air; kids huddled around each other while waiting for the bus would agree. Moving the air across the surface replenishes the air heated by the food with colder air, thus keeping "dT" at a high value for both Fourier's and Newton's laws. Fans are cheaper than lowering the cooler temperature. If you already have fans, check to see if all pieces are being exposed to the moving air; you may find some pieces huddled in the wind shadow of others, exposed only to preheated slow air. Another example of "h" is cold water and air; putting your hand into 50 degrees F. water chills it much faster than putting it into 50 degrees F. air. This is not surprising since the value of "h" for water is approximately 100 times the value of "h" for air.

d. The effect of "dT": Imagining an experiment for "dT" is hardly necessary since it is common knowledge that the colder the coolant, the quicker the food will cool; you wear heavier coats on colder days.

However, consider the magnitude of "dT" and how it affects the cooling rate. A "dT" of 60 degrees F. provides sufficiently rapid cooling for most purposes. Beyond that the limiting factor is the food's heat conductance; instead of cooling faster, the surface freezes. Since lower cooler temperatures cost more, processors might be able to economize by using coolant at ambient temperature (air or water) to bring the product temperature to within 50-60 degrees F. of ambient, then moving the product into the cooler. This would also lessen the heat load on the refrigeration system.

e. The effect of "k", "h", "A", & "L": We can bring several of these factors together by considering the cooling of boxed food. Boxing warm food products slows cooling because of several factors: (l) "h" is low because the food inside is exposed to still air, (2) the box adds an extra layer of insulation, thus decreasing "k", (3) many small pieces in a box become one large thermal mass, thus increasing "L" and decreasing "A". Therefore, it is not surprising to find food remaining above 70 degrees F. a day after putting in into a cooler, if was boxed while still warm. Boxed food can be cooled safely using a sufficiently cold blast freezer; however, removing a BTU of heat with a freezer costs much more than removing it with a cooler. These are factors the plant management should consider.

f. The thermal conductivity constant, "k": This affects both cooling rates and temperature monitoring. One common manifestation of the effect of "k" in food processing is the use of potato nails, aluminum spikes people stick in potatoes to hasten baking time. Because the aluminum conducts heat so much better than the potato, it is almost like cooking the potato from inside and outside at the same time. The principle works on both cooking and cooling and on meat as well as potatoes.

g. The effect of "k" and temperature measurement errors: Ignoring the effect of "k" can induce errors in temperature monitoring if the temperature probe is thick enough to transfer a significant amount of heat. An example of this can be seen by cutting into a roasted piece of meat, longitudinally, through the hole left by a thick temperature probe. The gray area beneath the surface of the meat will follow the hole into the interior of the meat for some distance. The gray area is the meat that has reached approximately 160 - 170 degrees F. The temperature probe, because it transfers heat much better than meat, raises the meat temperature around the probe to 160 - 170 degrees F. in less time. Errors in temperature monitoring occur when the probe shaft conducts heat to the probe tip and raises the probe tip to the critical temperature faster than the meat an inch or so away. The reverse can happen during cooling when the probe shaft transfers heat from the probe tip and causes an erroneously low reading.

Following is a list of practices that can minimize temperature measuring errors induced by "k"; since they have practical limits we suggest processors use them when practical.

(l) Use probes that are as thin as practical; a 1/8 inch diameter probe carries 4 times the heat that a 1/16 inch diameter probe carries; a 1/4 inch diameter probe carries 16 times the heat that a 1/16 inch probe carries.

(2) Use probes whose exposed metal shaft is thermally (not just electrically) insulated from the cooling (or cooking) medium.

(3) Instead of continuous monitoring, insert the probe only when a temperature reading is needed.

C. A COOLING PROBLEM CHECKLIST

1. The heat transfer coefficient, "h", for the coolant directly affects the rate of heat transfer. Since the value of "h" for forced convection air is approximately 5 times that of still air, the processor should check the following:

a. Does the cooler/freezer have fans?

b. Is the product exposed to the air or is it in a protective package?

c. Is the air circulating fully around the product or are some pieces protected from the wind?

d. Could the product be cooled by using chilled water or brine? Cold water has an "h" value approximately 50 times that of fanned air.

2. Maintaining a large difference in temperature (dT) between the product's center and its surface or the product and the coolant will assure rapid cooling. If the coolant warms significantly during the cooling cycle, then the later cooling stages will be slower and the processor should consider the following:

a. Should additional refrigeration capacity be installed to cool the amount of product being produced?

b. Is the refrigeration unit running optimally? For instance, are all coils clean, are all compressors properly maintained, are there no impediments to refrigerant flow, and is the refrigerant at optimum pressure?

c. Is hot product (>140 degrees F.) entering the cooler, thus overloading its capacity? If so, could the procedure be safely amended to permit the product to cool longer at ambient temperature before moving it into the cooler?

d. Is the refrigeration space managed effectively: does stacked product divert coolant flow, is the insulation effective, is there excessive traffic through the space, do doors remain open, and could door baffles help?

3. Although the thermal conductivity constant, "k", for meat is not high, it is approximately 30 times that of air and over 10 times the "k" value for many packaging materials. Thus, the processor should consider the following:

a. Is the product packaged in an insulating material, e.g. cardboard or plastic foam, before entering the cooler?

b. If the product is inside a thin film packaging material, are there significant air pockets acting as insulators?

c. Is the product directly exposed to the coolant or is there a thin tight film of packaging material between the coolant and the product? If so, the cooling problem may be elsewhere.

4. The area of product exposed to the coolant is another controllable factor.

a. Is the product exposed to the coolant on all sides?

b. Is part of the product covered by material with a low thermal conductivity value, e.g. thick plastic lugs or trays? If so, could they be replaced with materials with a higher "k" value, e.g stainless steel trays and lugs?

5. The longer the path the heat has to travel, the more time it takes. Thus, the processor should consider whether the present facilities are adequate for large products.

a. Can the product size be reduced in one or more dimensions?

b. Is the product being packed together so that it acts as one large piece?

If you have questions or want additional information on developing cooling control programs or improving your present program, please contact FSIS's Processed Products Inspection Division at the following address:

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You may contact us directly by telephone at (202) 447-3840 or address general questions through the FSIS Hotline at 800-535-4555.